DEPARTMENT OF THE ARMY
U. S. ARMY AVIATION SYSTEMS TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

(12) 21 p. (1)

SAVTE-TR (6)

(11) 29 FEB 1972

SUBJECT: (14) OH-58A Autorotational Evaluation, USAASTA Project No. 71-46

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1. REFERENCES. See inclosure 1.

2. ~~BACKGROUND~~ Several recent instances of tail-boom buckling have occurred after an autorotational touchdown in the OH-58A helicopter. These occurrences prompted the US Army Aviation Systems Command (AVSCOM) light observation helicopter (LOH) Project Manager to enter into a product improvement program (PIP) with Bell Helicopter Company (BHC) to define the problem and recommend a solution. This PIP task included computer studies, a shake test, and flight testing of a structurally instrumented OH-58A helicopter. The results of the PIP task, to date, indicate that the tail-boom buckling resulted from a resonant condition between the main rotor and the natural frequencies of the fore and aft pylon mode and the tail boom. This resonant frequency, 5 hertz, was likely to occur at high blade angles (100-percent collective) and low rotor speed (150 rpm) and was associated with large main rotor flapping excursions. Three solutions were considered: (1) change the natural frequencies of the fore and aft pylon mode and/or tail boom, (2) damp the pylon movement, and (3) eliminate the excessive blade flapping. The BHC chose the third solution by electing to restrict the maximum collective control travel which would, in turn, eliminate excessive flapping at low rotor speeds. The BHC testing showed that there was no degradation of helicopter performance as the result of the installation of an 80-percent collective pitch restriction device. Additional quantitative and qualitative data were desired by AVSCOM to ensure that performance degradation did not exist within the total OH-58A flight envelope. Accordingly, the US Army Aviation Systems Test Activity (USAASTA) was directed (ref 1, incls 1) to conduct a 3-day test program at the BHC flight test facility in Arlington, Texas. Additional testing at a high-altitude test site near Bishop, California, was directed by AVSCOM (ref 2).

3. TEST OBJECTIVE. The objective of this test program was to determine if the 80-percent collective pitch restriction on the OH-58A helicopter imposed a performance degradation of the autorotational landing performance (height-velocity (H-V)) flight envelope, and to demonstrate that this restriction reduced tail-boom loads to an acceptable level when performing autorotational landings at critical conditions.

4. DESCRIPTION. A standard production model OH-58A helicopter, modified only by the installation of structural loads instrumentation, was used during the portion of the test program conducted at the BHC facility. An OH-58A helicopter instrumented by USAASTA was used for the high-altitude flight test. Structural loads instrumentation was not included on this aircraft. The 80-percent collective restriction device was installed on both aircraft. A detailed description of the test aircraft is contained in reference 3, inclosure 1.

5. SCOPE OF TEST. Flight tests were conducted by a USAASTA test team at the BHC facility in Arlington, Texas. All maintenance support and data reduction services were provided by BHC during the portion of the test program performed at the BHC flight test facility. Tests were also conducted at a high-altitude test site near Bishop, California. During the high-altitude test, all logistics support and data processing were accomplished by USAASTA. A total of 6 hours of productive flight test time was required to complete these tests. The test conditions are shown in table 1.

Table 1. Test Conditions.[1]

| Test Site | Gross Weight (lb) | Density Altitude (ft) | Gross-Weight/ Density Ratio | Temperature (°C) |
|---|---|---|---|---|
| BHC[2] | 2,990 | -340 | 2,960 | +7 |
| | 2,970 | -700 | 2,910 | +7 |
| Bishop[3] | 2,450 | 2,130 | 2,650 | -4 |
| | 2,640 | 3,370 | 2,920 | +2 |
| | 2,840 | 2,620 | 3,070 | -5 |
| Coyote Flats[3] | 2,540 | 9,670 | 3,400 | -2 |

[1]Wind speed: 4 to 7 knots.
[2]Center of gravity: FS 109.7.
[3]Center of gravity: FS 107.0.

6. METHODS OF TEST. The flight test methods described in reference 4, inclosure 1, were utilized throughout the test program. At the BHC flight test facility, a ground-operated phototheodolite grid camera and an airborne oscillograph were used. At the high-altitude test sites, a Fairchild Flight Analyzer and an oscillograph were used to record data.

7. CHRONOLOGY. The chronology of the testing is as follows:

| | | | |
|---|---|---|---|
| Test directive received | 22 | November | 1971 |
| Flight tests initiated (BHC) | 22 | November | 1971 |
| Flight tests completed (BHC) | 24 | November | 1971 |
| Additional requirements received | 3 | December | 1971 |
| High-altitude tests initiated | 6 | December | 1971 |
| High-altitude tests completed | 17 | December | 1971 |
| Preliminary message report dispatched | 21 | December | 1971 |
| Project Manager debriefed | 28 | December | 1971 |

8. RESULTS AND DISCUSSION. a. General. Test results show that the reduction of collective control travel did not eliminate the excitation of the tail-boom resonance. It did, however, extend the touchdown airspeed envelope within which tail-boom resonance does not occur. The unacceptable tail-boom resonance characteristic is a deficiency, correction of which is mandatory. The autorotational landing performance of the OH-58A helicopter was degraded with the 80-percent collective control travel restriction at density altitudes greater than 5,000 feet.

b. Tail-Boom Resonance. A time history of an autorotational landing is presented in figure 1, inclosure 2. Shown in these data are the conditions under which tail-boom resonance was encountered during tests at the BHC flight test facility. The horizontal touchdown velocity at the time of the occurrence of the tail-boom resonance was estimated to be 40 knots. This airspeed was in excess of touchdown speeds which are normally used during flight operations. The structural loads experienced during this incident were not severe enough to cause failure of the tail boom; however, a 6-inch crack developed in the fiberglass fairing just forward of the tail-boom attaching point. As evidenced by the flight test data, the 80-percent restriction of collective control travel did not eliminate the excitation of tail-boom resonance. It did, however, extend the touchdown airspeed envelope within which tail-boom resonance did not occur. Immediate action should be initiated to eliminate the tail-boom resonance deficiency. As an interim measure to reduce the incidences of tail-boom resonance during autorotational landings, flight test techniques developed during USAASTA Project No. 69-16 (ref 4, incls 1) should be employed. Use of these techniques results in touchdown with rotor speed remaining in excess of 200 rpm. To demonstrate these techniques, a USAASTA test team should be sent to the Continental Army Command (CONUS) training sites. The following "WARNING" should be incorporated in the OH-58A operator's manual:

WARNING

Touchdown autorotations with rotor speed below 200 rpm may result in tail-boom resonance.

c. Autorotational Landing Performance.

(1) Qualitative test results indicate that the reduction of collecti[ve] control travel had little or no effect on the H-V characteristics of the OH-58A [u]nder the conditions tested at the BHC facility. The test conditions are shown i[n] [T]able 1. Figure 2, inclosure 2, shows a typical H-V maneuver and denotes actual c[on]ditions at entry and termination of the maneuver. As shown in this figure, the rotor speed at ground contact is in excess of 250 rpm.

(2) Incorporated in figure 3, inclosure 2, are data collected during recent high-altitude tests with the collective control restricted to 80 percent of full travel. These recent data indicate that the H-V characteristics of the OH-58A are degraded at density altitudes greater than 5,000 feet. Also shown in figure 3 are the near maximum performance and the recommended operational curves generated during USAASTA's previous H-V test program, Project No. 69-16 (ref 4, incls 1). The techniques utilized during the recent test program were the same as those developed during the conduct of Project No. 69-16.

(3) Time histories of selected data points shown in figure 3, inclosure 2, are presented in figures 4 through 13. These time histories denote the test data generated with the collective control travel restricted to 80 percent of full travel. Figures 7, 8, and 10 show that maximum available collective control was used to complete the maneuver. Qualitative pilot comments indicate that additional collective would have been used were it available.

(4) Figures 14 and 15, inclosure 2, are additional data specifically requested by AVSCOM. These figures show data points collected for the recommended operational curve which resulted from Project No. 69-16 testing along with the maximum pitch rates and attitudes utilized. These data are presented to facilitate determination of consistency of pilot technique.

9. CONCLUSIONS. a. General. The following conclusions were reached upon completion of the autorotational evaluation of the OH-58A helicopter:

(1) The 80-percent collective control restriction did not eliminate the excitation of tail-boom resonance (para 8b).

(2) The 80-percent collective control restriction extended the touchdown airspeed envelope within which tail-boom resonance did not occur (para 8b).

(3) The use of autorotational landing techniques developed during USAASTA Project No. 69-16 results in touchdown with rotor speed remaining in excess of 200 rpm (para 8b).

(4) The autorotational landing performance characteristics (H-V) of the OH-58A helicopter are degraded at density altitude in excess of 5,000 feet (para 8c(2)).

b. Deficiency Affecting Flight Safety. Correction of the unacceptable tail-boom resonance characteristic is mandatory (para 8b).

10. RECOMMENDATIONS. The following recommendations are made:

a. The deficiency, correction of which is mandatory, should be corrected as soon as possible.

b. A USAASTA team should be sent to the CONUS training sites to instruct standardization instructor pilots in the autorotational landing techniques developed during the conduct of Project No. 69-16.

c. The following "WARNING" should be incorporated in the OH-58A operator's manual:

WARNING

Touchdown autorotations with rotor speed below 200 rpm may result in tail-boom resonance.

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## REFERENCES


1. Test Directive, AVSCOM, No. 71-46, subject: OH-58A Autorotational Evaluation, 19 November 1971.

2. Message, AVSCOM, AMSAV-EFS, 2 December 1971, Unclas, subject: Additional Requirements, OH-58A Autorotational Evaluation, Project No. 71-46.

3. Technical Manual, TM 55-1520-228-10, *Operator's Manual, Army Model OH-58A Helicopter*, 13 October 1970, with Change 3, 15 April 1971.

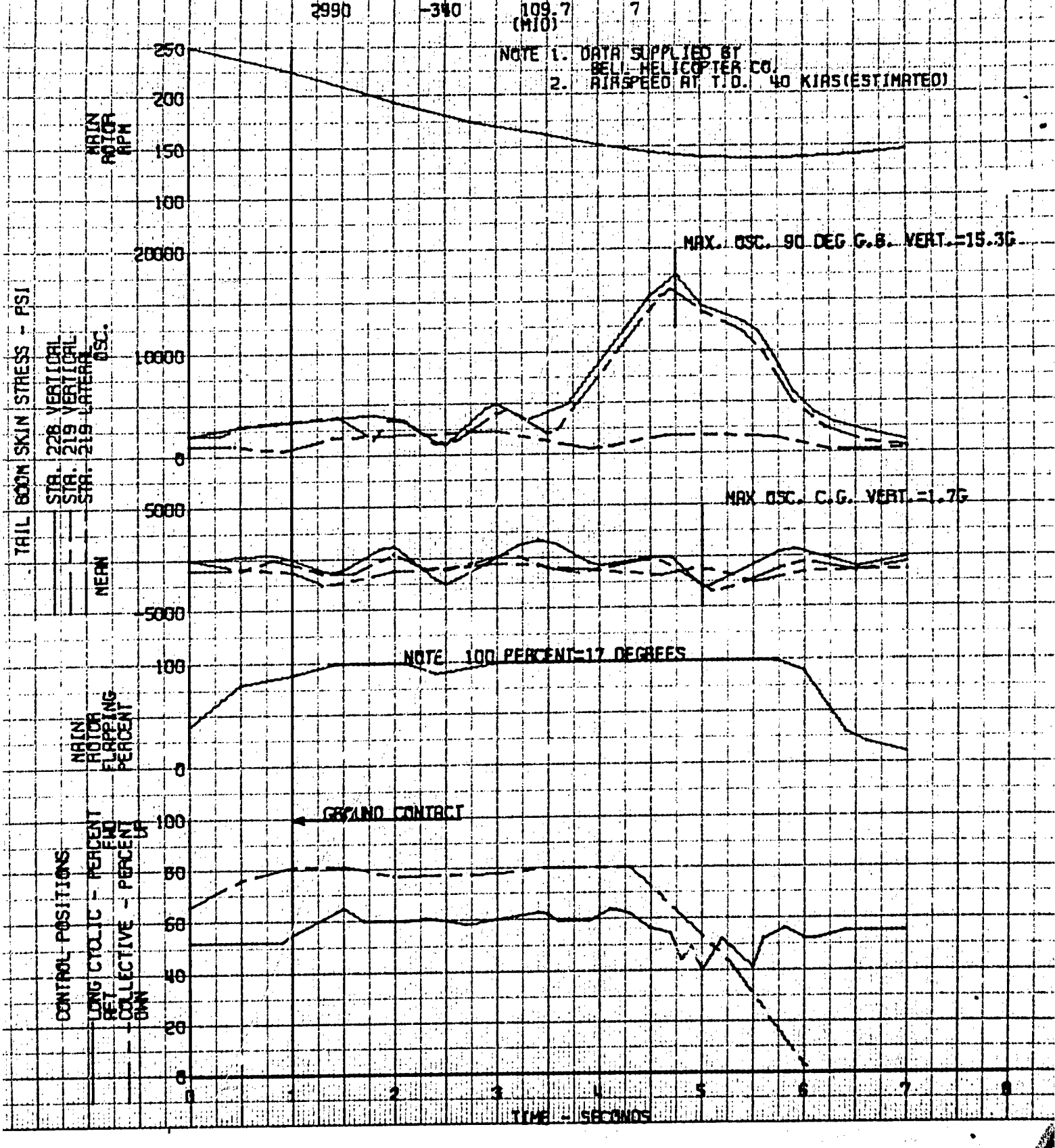
4. Final Report, USAASTA, Project No. 69-16, *Height-Velocity Test, OH-58A Helicopter*, June 1971.

# FIGURE 1
## TIME HISTORY OF AUTOROTATIONAL LANDING

OH-58A S/N 41155

| GROSS WEIGHT LBS | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|
| 2990 | -340 | 109.7 (MIO) | 7 |

NOTE 1. DATA SUPPLIED BY BELL HELICOPTER CO.
2. AIRSPEED AT T.D. 40 KIAS(ESTIMATED)

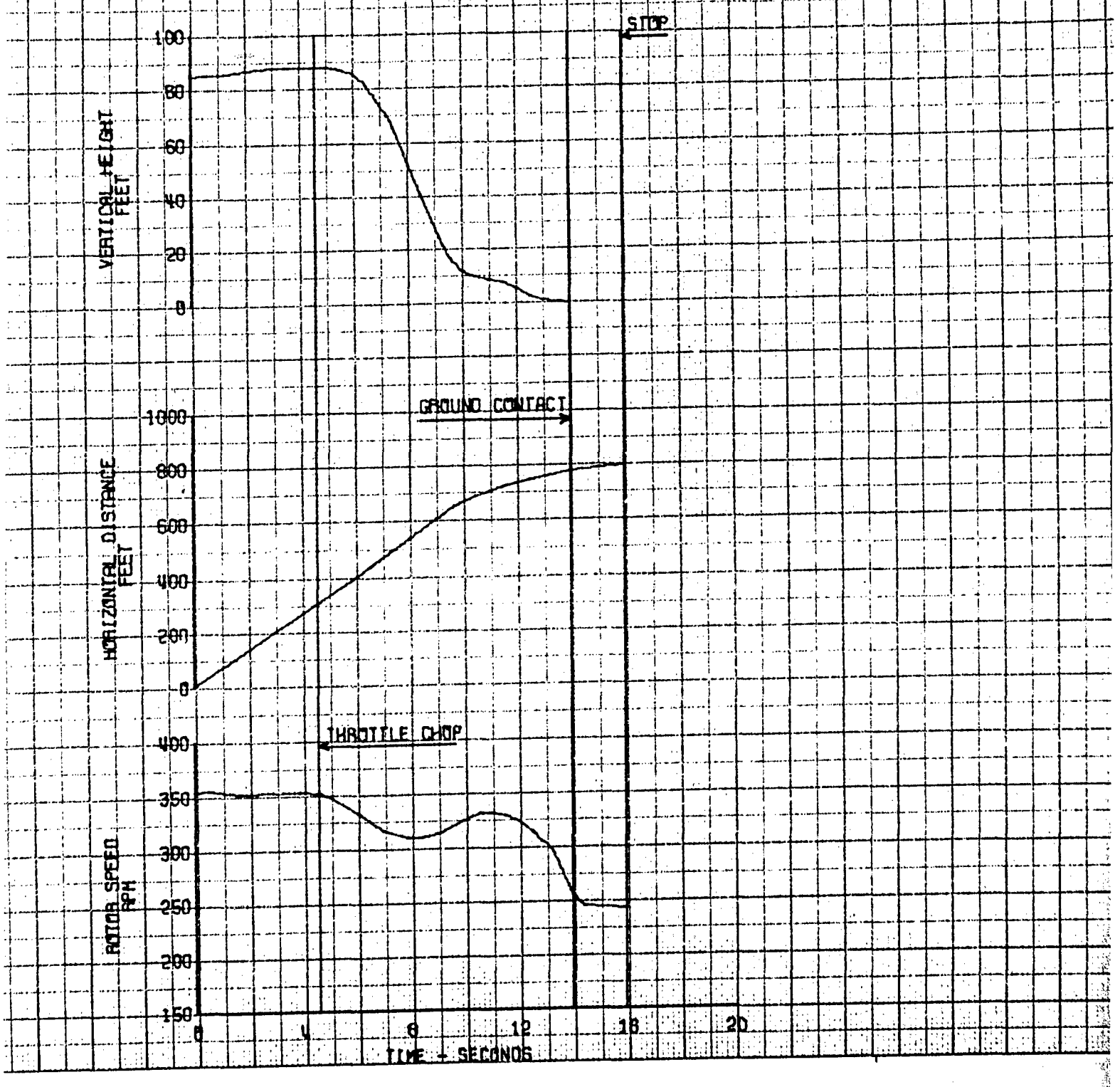


# FIGURE 2
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 41155

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT(AGL) | GROSS WEIGHT LBS | CENTER OF GRAVITY F.S. | DENSITY ALTITUDE FEET | COLLECTIVE AT T.O. PERCENT | GRD SPEED AT T.O. KNOTS | FREE AIR TEMPERATURE DEG. C |
|---|---|---|---|---|---|---|---|
| 45 | 88 | 2260 | 109.7 (MID) | -700 | 67 | 10 | 7 |

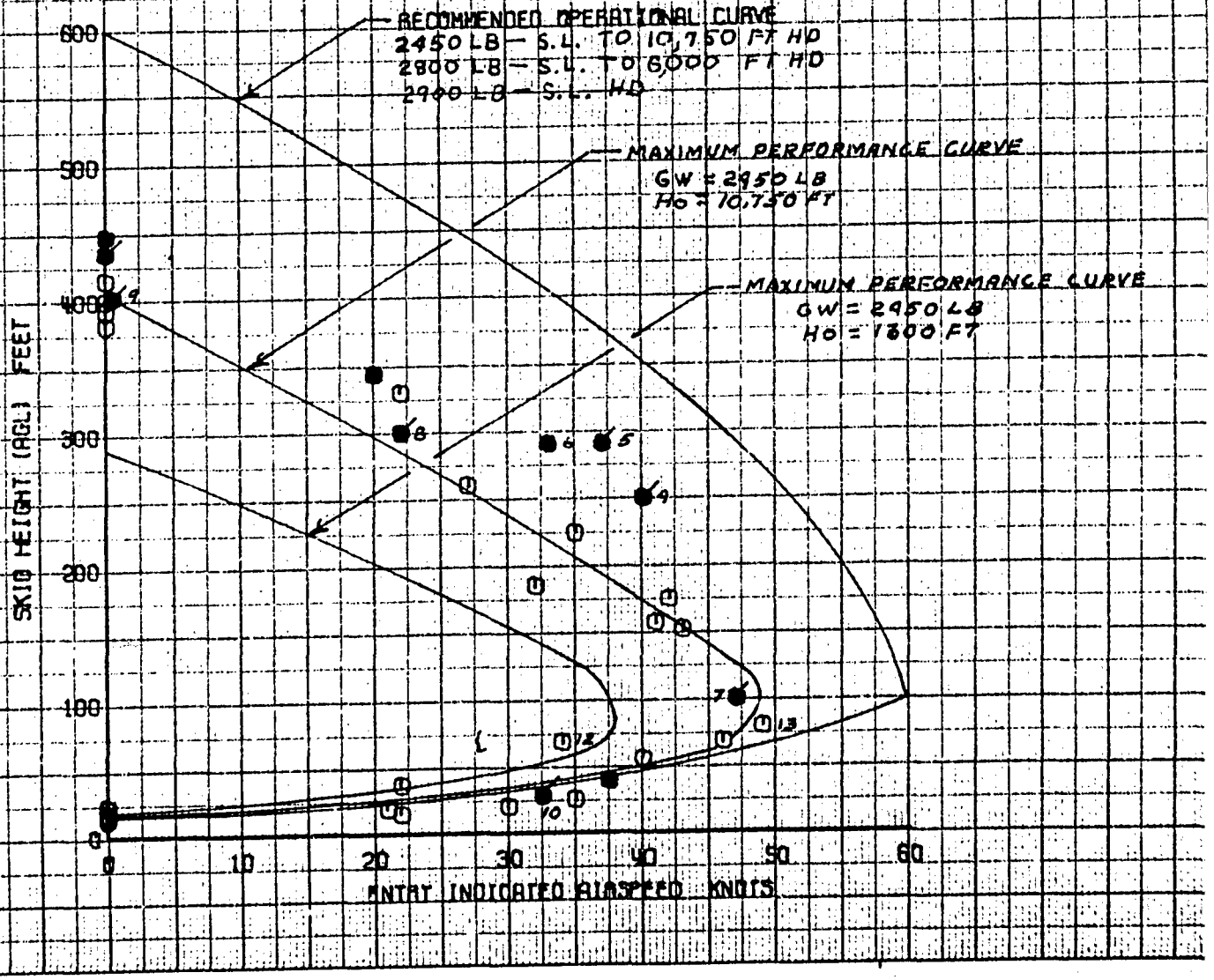
NOTE 1. DATA SUPPLIED BY BELL HELICOPTER CO.



# FIGURE 3
## HEIGHT VELOCITY PROFILES

### MAXIMUM PERFORMANCE CURVES AND RECOMMENDED OPERATIONAL CURVE

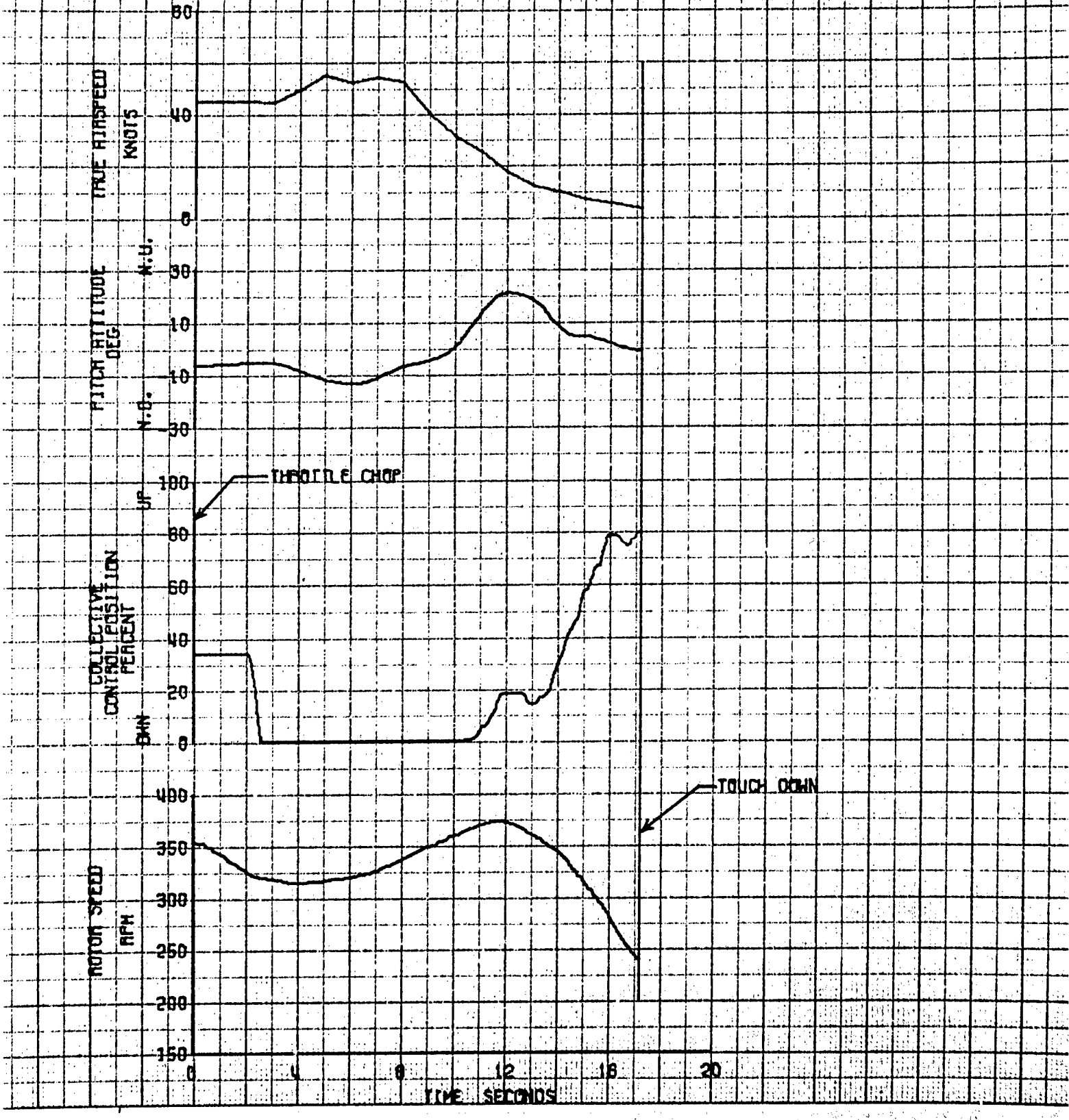
NOTE 1. CURVES EXTRACTED FROM FINAL REPORT USAASTA PROJ. NO. 69-16.
2. OPEN SYMBOLS INDICATE DATA POINTS WHERE MORE THAN 75 PERCENT OF FULL COLLECTIVE TRAVEL WAS USED (PROJ. NO. 69-16)
3. SHADED SYMBOLS - COLLECTIVE TRAVEL LIMITED TO 80 PERCENT.
4. FLAGGED SYMBOLS - 80 PERCENT STOP CONTACTED DURING MANEUVER.
5. NUMBERED SYMBOLS INDICATE TIME HISTORY FIGURE NUMBERS.



# FIGURE 4
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

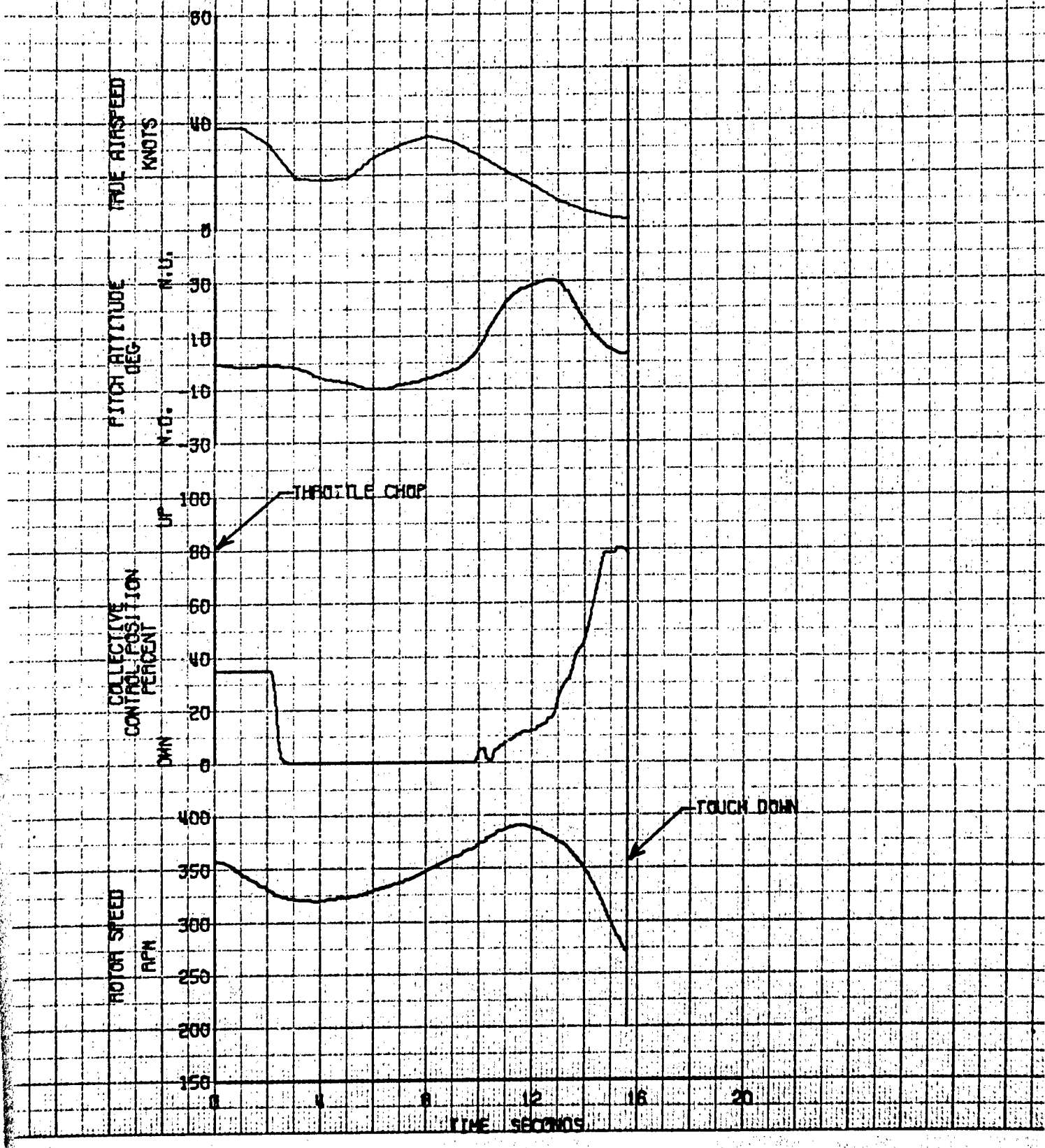
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 40 | 250 | 2450 | 2130 | 107.0 (FWD) | 2650 | -3 |



# FIGURE 5
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

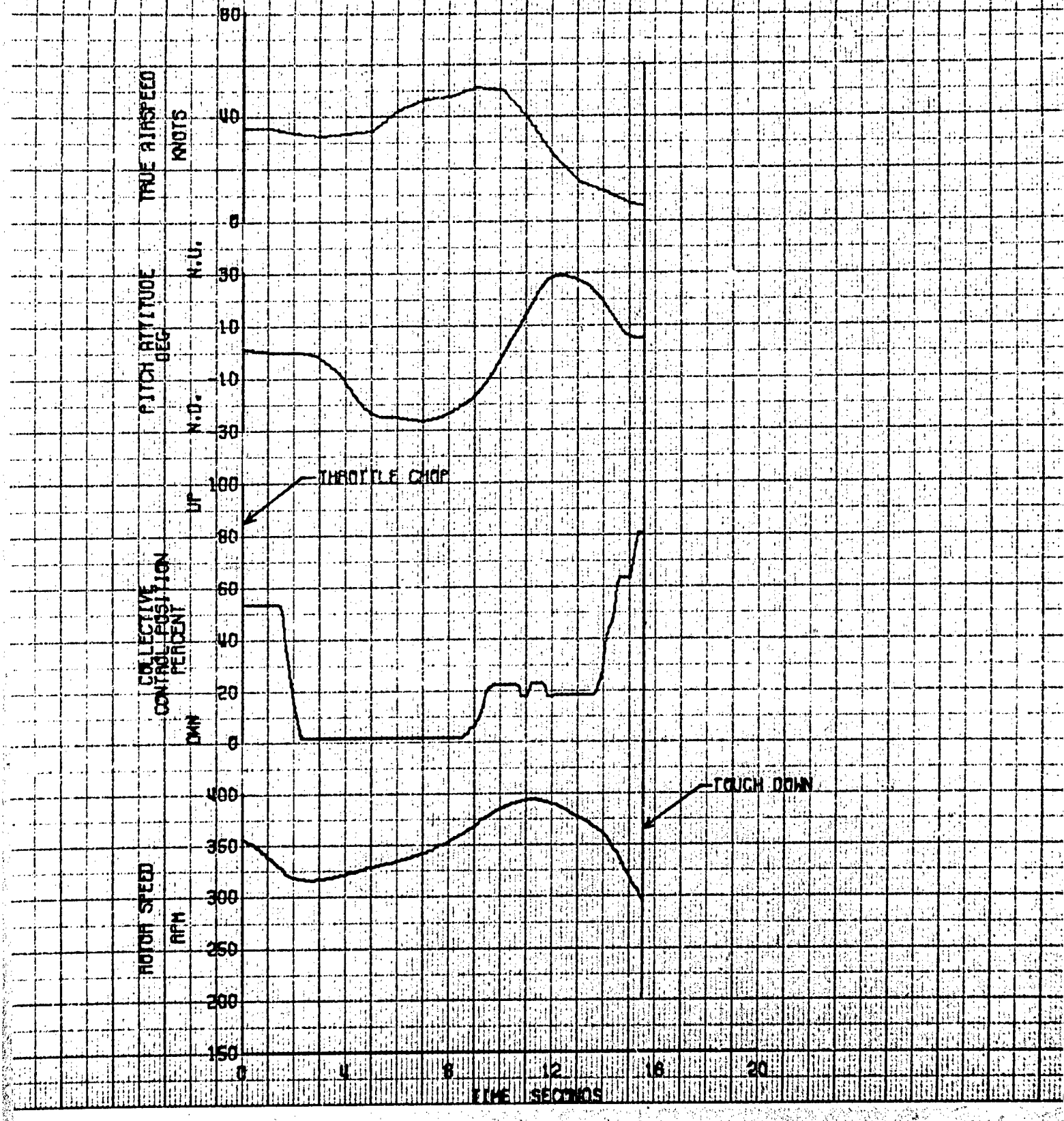
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 37 | 290 | 2640 | 3370 | 107.0 (FWD) | 2920 | 2 |



# FIGURE 6
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

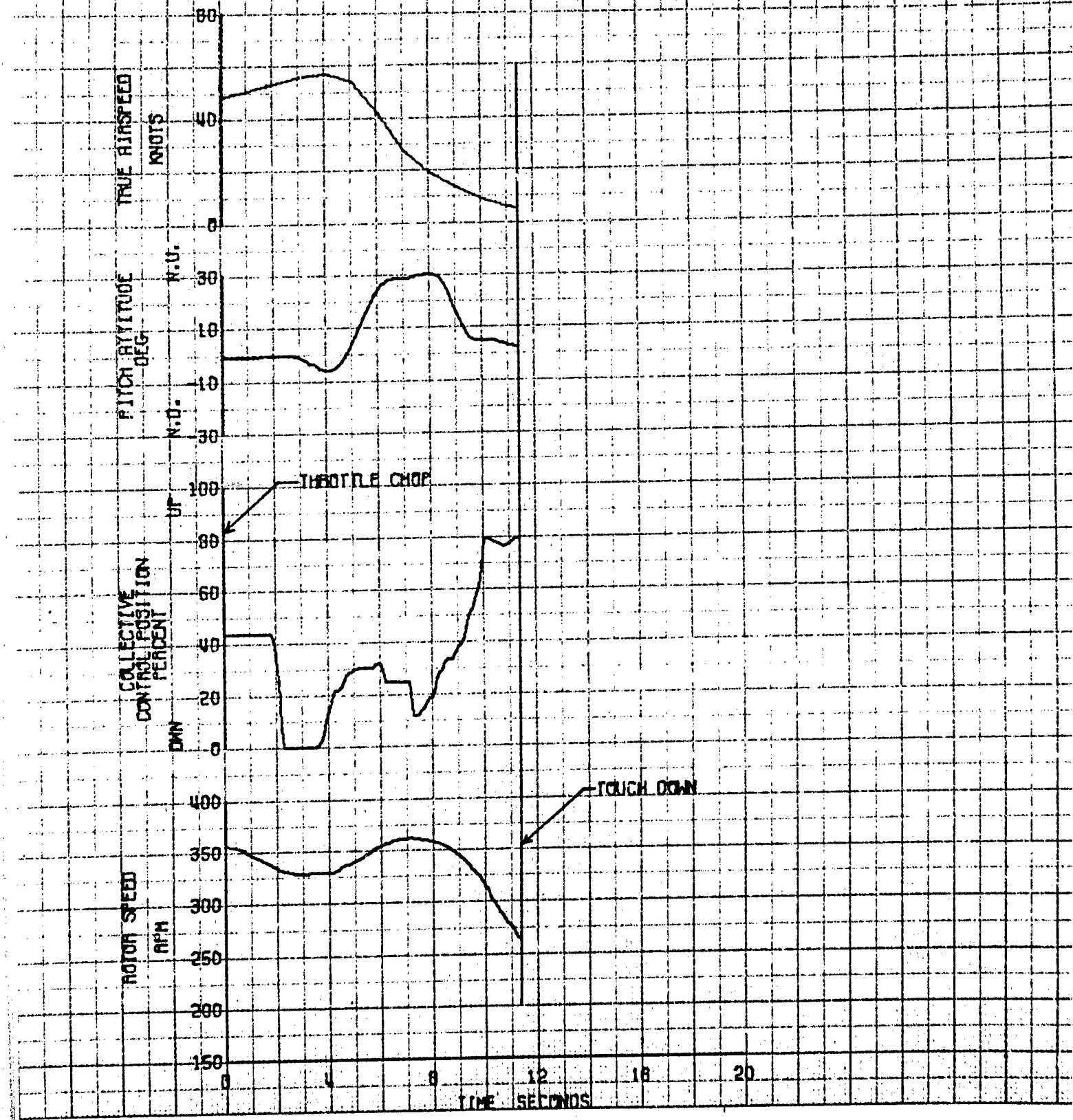
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 33 | 290 | 2840 | 2620 | 107.0 (FWD) | 3070 | -6 |



# FIGURE 7
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

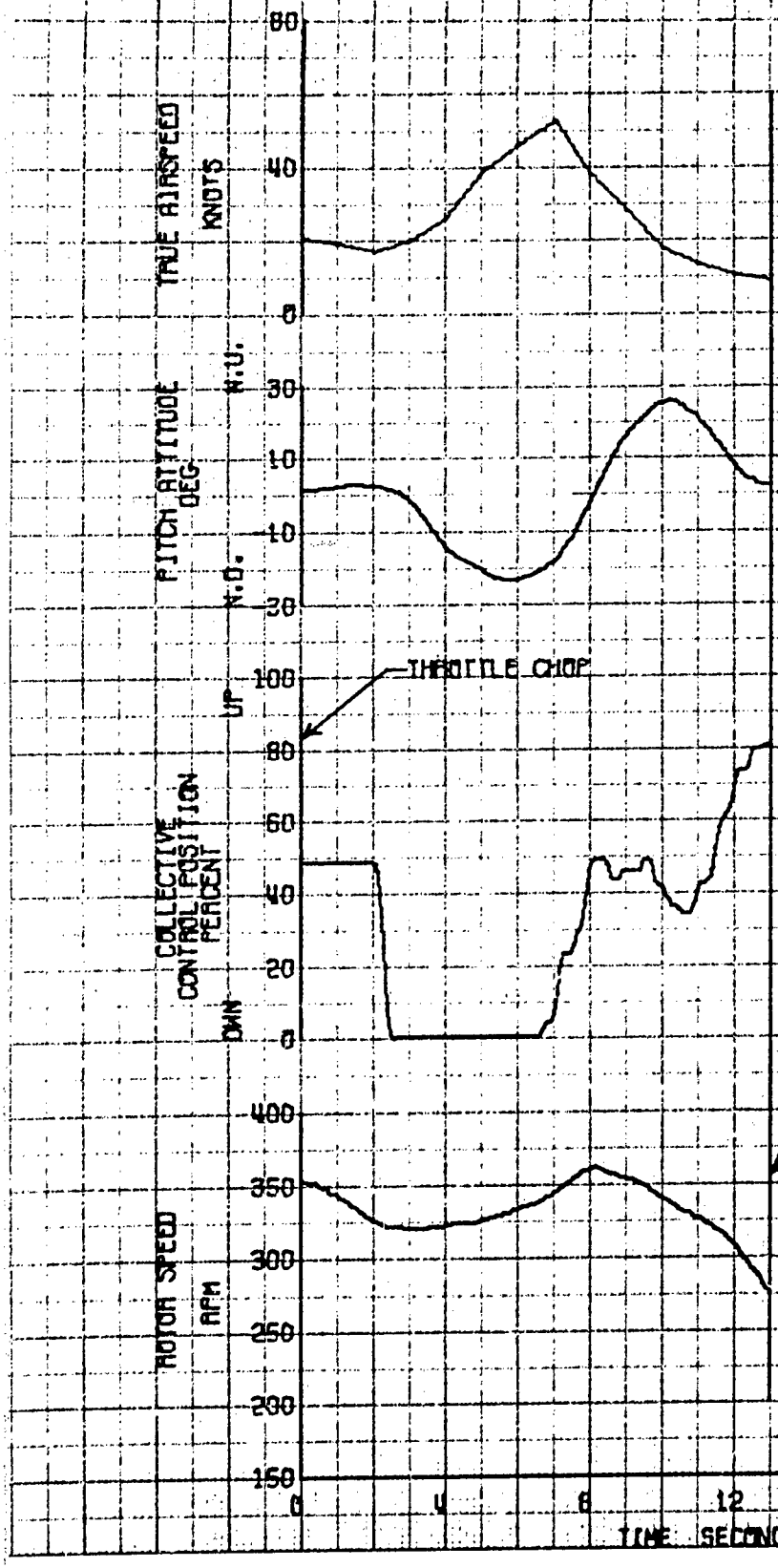
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 47 | 100 | 2540 | 9670 | 107.0 (FWD) | 3400 | +2 |



# FIGURE 8
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

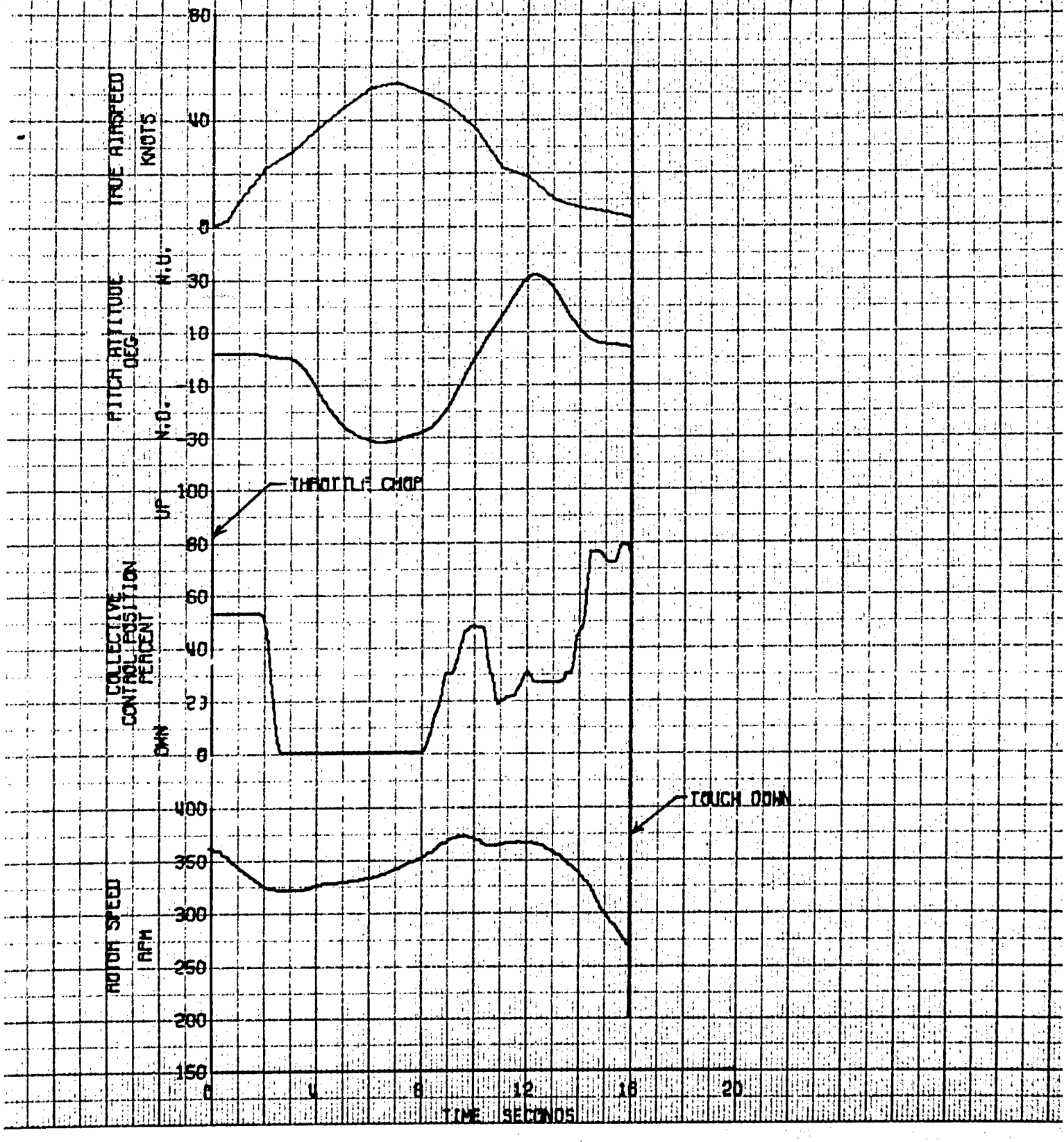
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 20 | 320 | 2540 | 9670 | 107.0 (FWD) | 3400 | -3 |



# FIGURE 9
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16708

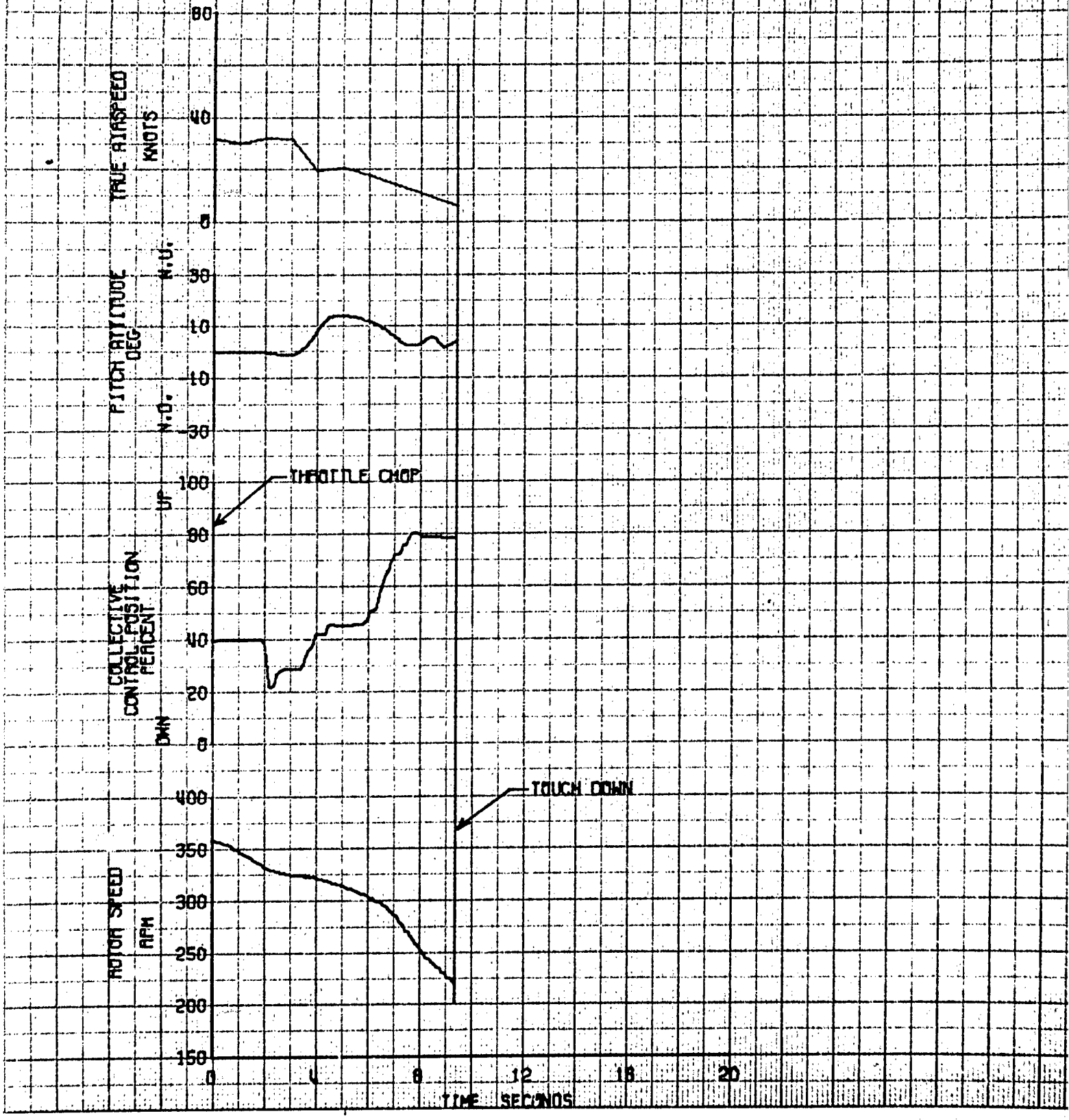
| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GROSS WEIGHT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| HOVER | 400 | 2540 | 9670 | 107.0 (FWD) | 3400 | +2 |



# FIGURE 10
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 33 | 30 | 2540 | 9670 | 107.0 (FWD) | 3400 | -2 |



# FIGURE 11
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE-AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 32 | 190 | 2440 | 6110 | 107.0 (FWD) | 2940 | 24 |

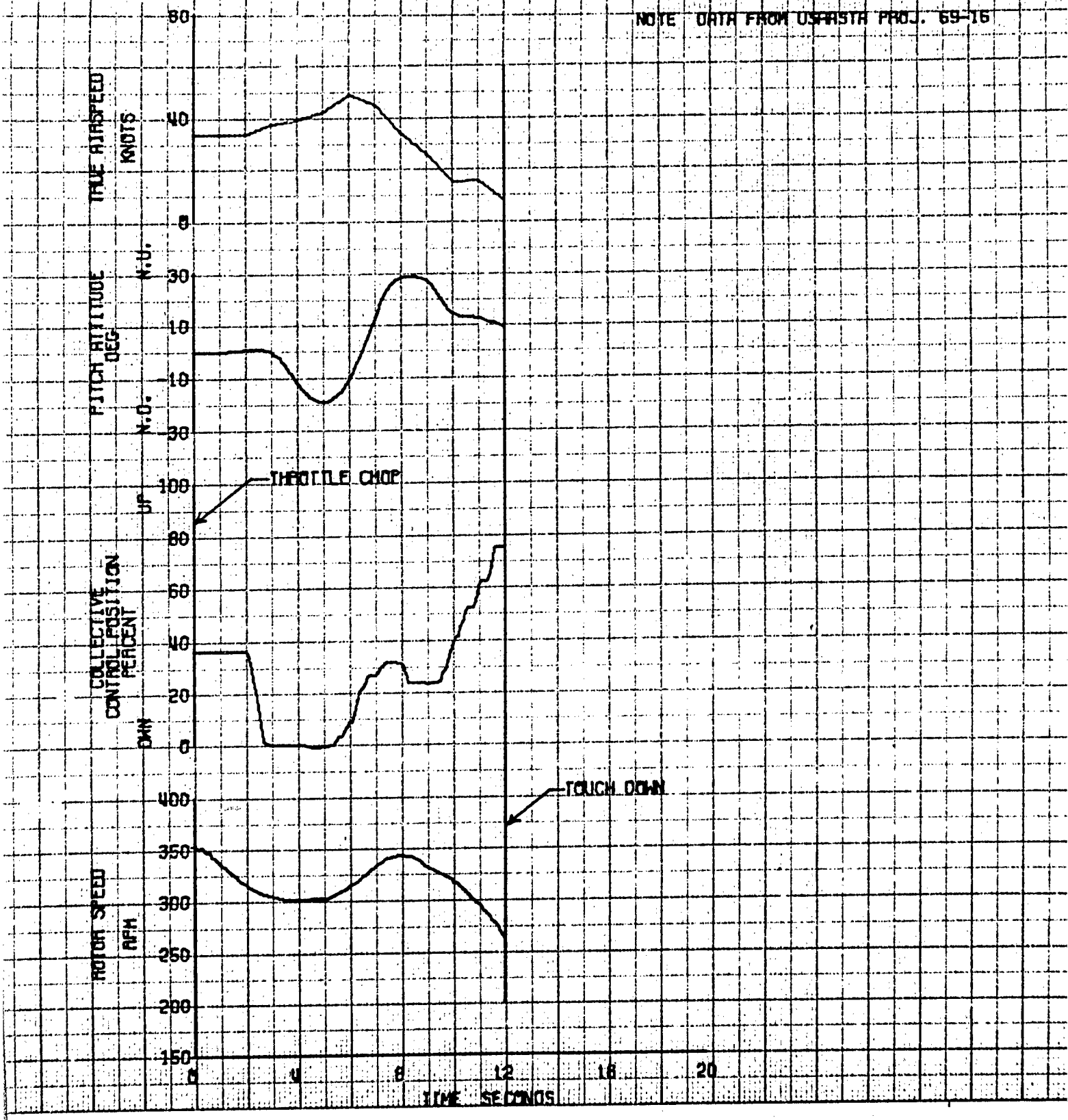
NOTE DATA FROM USAASTA PROJ. 69-16

# FIGURE 11
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 32 | 190 | 2480 | 6110 | 107.0 (FWD) | 2940 | 24 |

NOTE DATA FROM USAASTA PROJ. 69-16

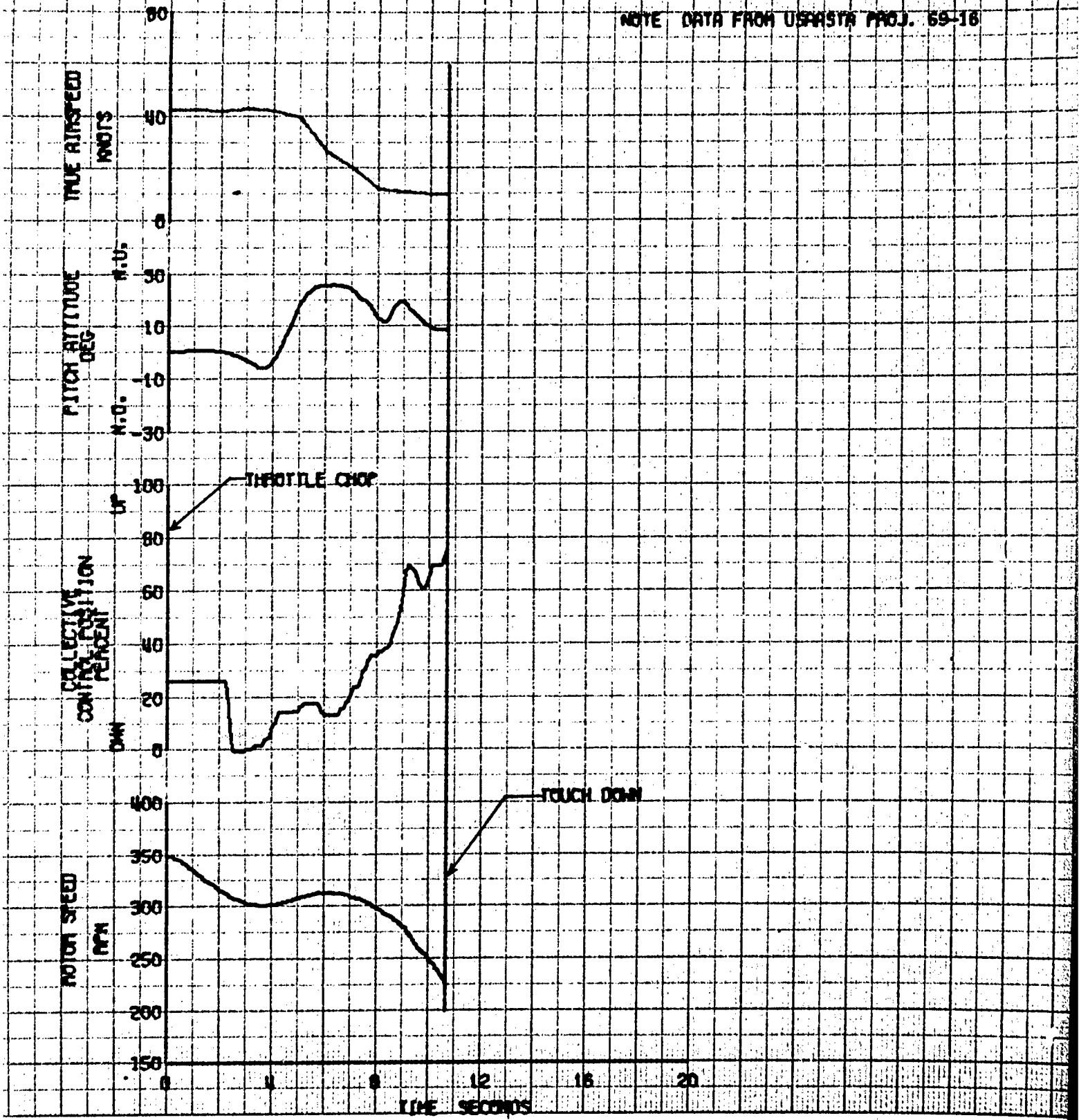


# FIGURE 12
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 66-16706

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GR WT F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 34 | 70 | 2440 | 1280 | 107.0 (FWD) | 2540 | 22 |

NOTE DATA FROM USAASTA PROJ. 69-16

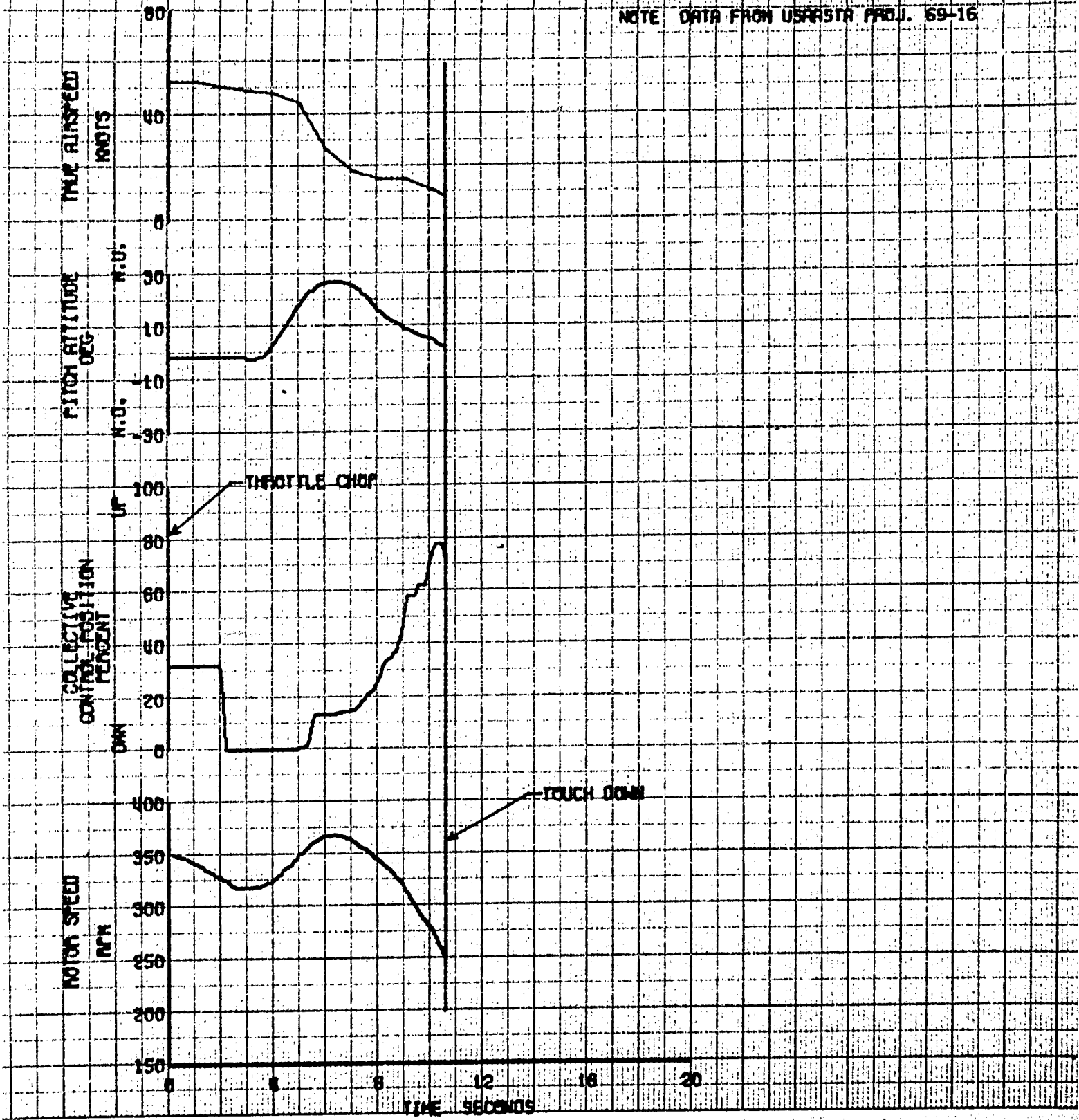


# FIGURE 13
## HEIGHT VELOCITY TIME HISTORY

OH-58A S/N 68-16706

| ENTRY AIRSPEED KIAS | ENTRY HEIGHT FT (AGL) | GROSS WEIGHT LB | DENSITY ALTITUDE FEET | CENTER OF GRAVITY F.S. | GROSS WEIGHT LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|---|
| 49 | 80 | 2790 | 3760 | 107.0 (FWD) | 3400 | 6 |

NOTE DATA FROM USARSTA PROJ. 69-16



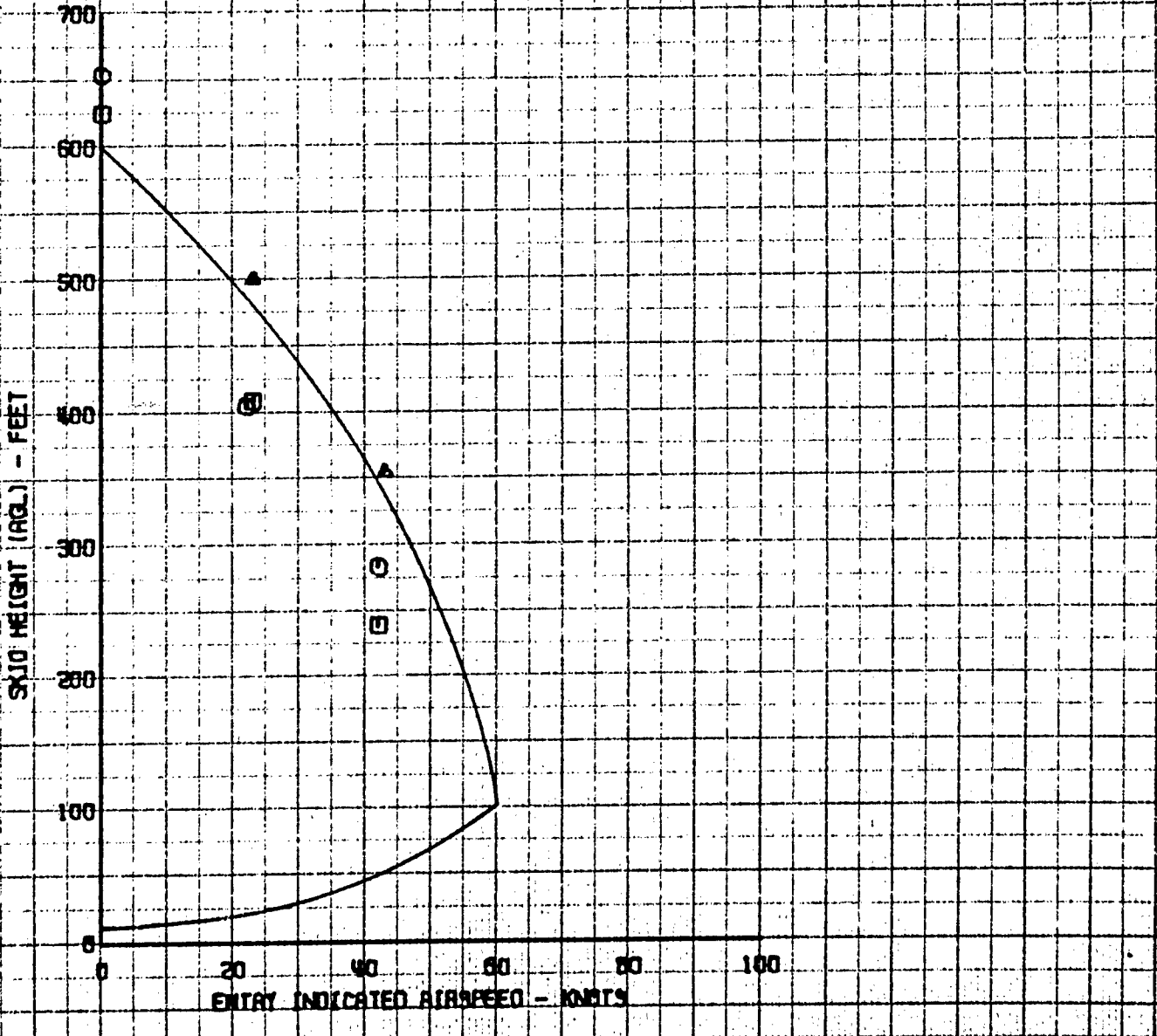
# FIGURE 14

## RECOMMENDED OPERATIONAL HEIGHT VELOCITY PROFILE

OH-58A S/N 68-16706

| SYMBOL | GROSS WEIGHT LB | DENSITY ALTITUDE FT | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|
| □ | 2450 | 4900 | 107.0(FWD) | 3220 | 10 |
| ○ | 2800 | 4600 | 107.0(FWD) | 2840 | 8 |
| △ | 2460 | 11100 | 107.0(FWD) | 3450 | 6 |

NOTE 1. BASED ON SIMULATION OF PITCH ATTITUDES AND PITCH RATES UTILIZED BY OPERATIONAL ARMY AVIATORS.
2. A 2 SECOND DELAY FROM THROTTLE CHOP TO COLLECTIVE REDUCTION.
3. 2450 LB-S.L. TO 10,750 FT-HD
2800 LB-S.L. TO 6,000 FT HD
2900 LB-S.L. HD
4. DATA FROM USAASTA PROJ. 69-16



# FIGURE 15
## MAXIMUM PITCH ATTITUDES AND RATES DURING PUSHOVER
### OPERATIONAL AND MAXIMUM PERFORMANCE CURVE POINTS

| SYMBOL | GROSS WEIGHT LB | DENSITY ALTITUDE FT | CENTER OF GRAVITY F.S. | GR WT SIGMA LB | FREE AIR TEMPERATURE DEG C |
|---|---|---|---|---|---|
| □ | 2450 | 6400 | 107.0 (FWD) | 2950 | 22 |
| ○ | 2800 | 5400 | 106.7 (FWD) | 3300 | 15 |
| △ | 2460 | 11100 | 107.0 (FWD) | 3440 | 6 |

NOTE 1. OPEN SYMBOLS DENOTE MAXIMUM PERFORMANCE CURVE POINTS
2. SHADED SYMBOLS DENOTE OPERATIONAL CURVE POINTS
3. DATA FROM USAASTA PROJ. 69-16